Evaluating and Analyzing the Sustainable Development using PCA

a case study in Honghu city China

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***Abstract*-The Principal Component Analysis (PCA) method can be used for managing numerous correlative indexes. In this paper we attempt to apply this method to evaluating and analyzing the sustainable development, a case study in Honghu City China. Firstly, according to the theory of system, we regard Honghu City as one compound system including population, economy, society, and resource environment subsystems, and set up evaluation index system of Honghu city. Then evaluate and analyze the state of sustainable development using PCA. The results show: Honghu city develops towards the benign direction generally, and some reasons for the development state are analyzed. Above evaluation and analysis process indicate: PCA is a good method to evaluate and analyze sustainable development.**

Keywords-evaluating, analyzing, sustainable development, PCA, Honghu City China

Ⅰ. INTRODUCTION

Building a sustainable development city is an international development trend. How to appraise the state of sustainable development of the city more objectively, it has been a hot problem studied in sustainable development field at all times. This paper takes Honghu city in China as an example, has tried to use The Principal Component Analysis (PCA) method to appraise the state of sustainable development of this city. The analyzed instance indicates: the analysis result has reflected the current situation of the sustainable development of the area objectively, can offer the theoretical foundation for the administrative departments that make the development scheme and policy.

Ⅱ. DATA AND METHODOLOGY

A. Study site

The study site is the important sector that develops economy along the Yangtze River, located between 113° 07'-114° 05'E, 29° 39'-30° 02'N, in the southeast of Jianghan plain China, bordering on the Yangtze River in the east. Geographical environment is superior. Honghu city covers an area of approximately 2528 km^2, and holds population 896.4 thousand.

B. Choosing index system

After investigating Honghu city, combining its area characteristics, such as level, related, regional, dynamic and controllable, we regard Honghu city as a compound system including population, economy, society, and resource environment subsystems and each subsystem includes lower level subsystems again. Compound system has complicated structure and more levels. Between system and the external environment, system and subsystem, exit interaction. So it is difficult to set up an index system that can reflect all development information of the area. In the course of practical operation, combining the actual conditions of this area and existing condition of work, according to the scientific, effective, comprehensive, independent, and pertinent principle, we set up evaluation index system of sustainable development of Honghu city.

We elected 44 indexes that can reflect this current situation of the development from numerous statistics and the survey data including 6 population subsystems, 11 economy subsystems, 18 society subsystems, 9 resource environment subsystems. In the 44 indexes chosen, there may be remarkable indexes dependence between every two, which will cause indexes overlap during computation process, so it is necessary to inspect dependence to the indexes selected.

We classify the indexes chosen based on subsystem and calculate the correlation coefficient between every two indexes in every subsystem, and get the matrix of the coefficient correlation. Then elect coefficient correlation $r>0.9$ indexes, judge whether to belong to false relevance or not. Finally combining the system characteristic and position in the index system, we reject the indexes belong to false relevance and receive the evaluation index system of sustainable development of Honghu. (As Fig. 1 shows)

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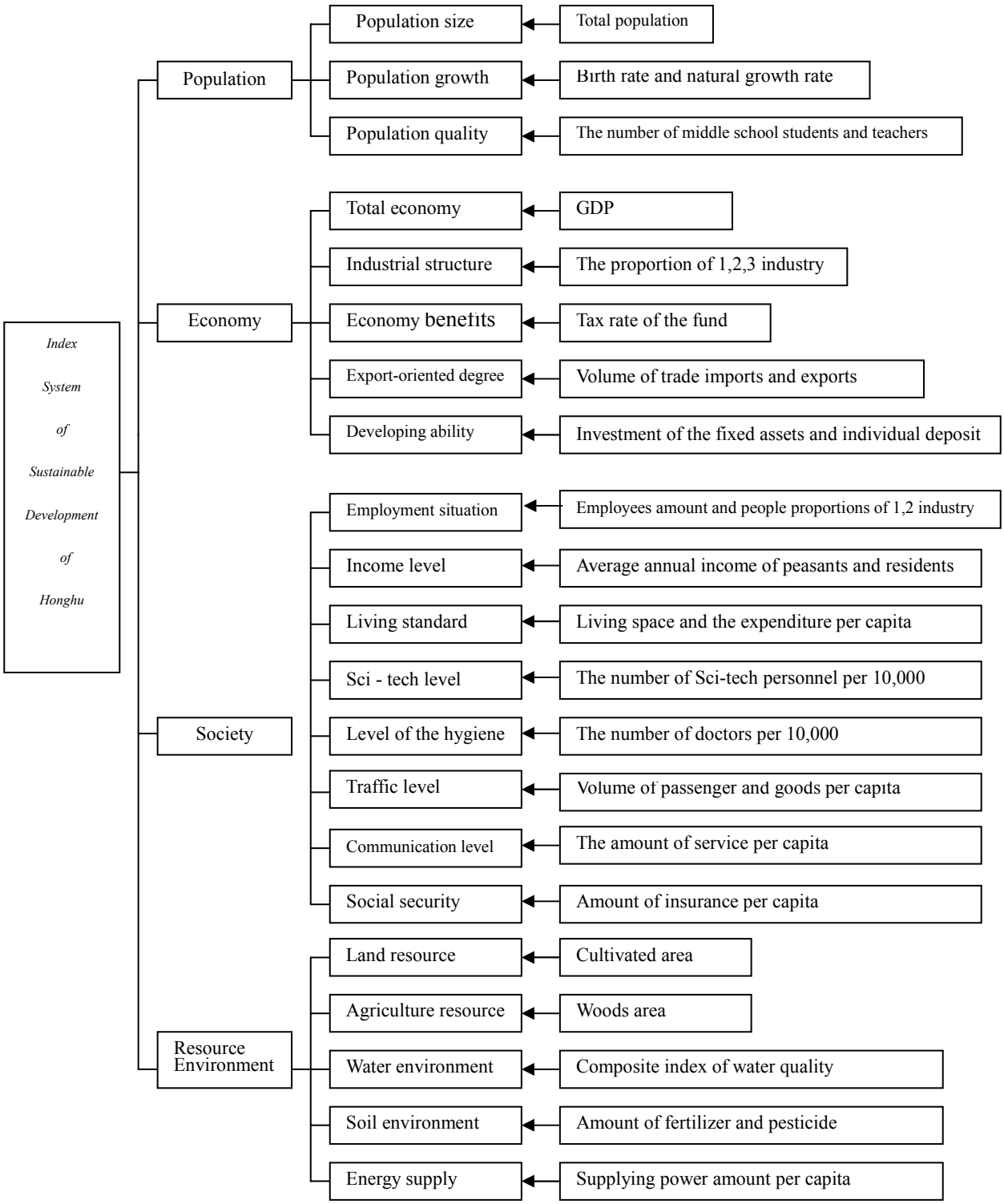


Fig.1 Index system picture of sustainable development of Honghu

C. Method of evaluating the sustainable development of Honghu---- PCA

When evaluating the sustainable development of Honghu city, we need to deal with a large number of indexes. Between the indexes there is dependence. So if appraisal method selected is improperly, not only the workload is heavy, but apt to cause the distorted results. The Principal Component

Analysis (PCA) method, its working object is a data list including sample variable x, its performance goal is to fall dimension under the principle of guaranteeing to lose the least information. Because the principal component is positive crossed each other, we can dispel dependence and simplify data list with multi-variable on the premise of guaranteeing the sufficient amount of information, its calculation procedure is as follows:

Primitive several

$$X=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix}$$, was treated quantitatively

$$X_{aj}^{*}=\frac{x_{aj}-\overline{x_j}}{\sigma_i};$$

among them, $\overline{x_j}=\frac{1}{N}\sum_{A}x_{aj}$; $\sigma_j^2=\frac{1}{N}\sum_{a}(x_{aj}-\overline{x_j})^2$

We calculate the Matrix of the coefficient correlation r

$$r=\frac{\frac{1}{N}\sum_{a}(x_{aj}-\overline{x_i})(x_{aj}-\overline{x_j})}{\sigma_i\sigma_j}=\frac{1}{N}\sum_{a}x_{ai}^{*}x_{aj}^{*}$$

According to the Characteristic Equation $|R-\lambda I|=0$,calculate the Characteristic Value，that is to say, solve the multinomial: $r_{n\lambda}^{p}+r_{(n-1)\lambda}^{p-1}+\cdots+r_{1\lambda}+r_0=0$, receive: $\lambda_1,\lambda_2,\cdots,\lambda_p$,and arrange from great to small，such as $\lambda_1\geq\lambda_2\geq\cdots\geq\lambda_p\geq 0$ .List Characteristic vector of λ_k: $L_k=[L_{k1},L_{k2},\cdots,L_{kp}]^T$.

Calculate the contribution rate: $\lambda_k/\sum_{i=1}^{p}\lambda_i$ and accumulative contribution rate: $\sum_{j=1}^{k}(\lambda_i/\sum_{i=1}^{p}\lambda_i)$ and receive the Characteristic Value of the accumulative contribution rate >90%, $\lambda_1,\lambda_2,\cdots,\lambda_m$ (m≤p).

Calculate the load of principal component:

$$P(Z_k,X_i)=\sqrt{\lambda_k}L_{ki},(i=1,2,\cdots,m)$$

Load of principal component is coefficient correlation between the principal component Z_k and the variable X_i

Calculate the comprehensive appraisal value:

$$F=(\lambda_1/\sum_{i=1}^{7}\lambda_i)F_1+(\lambda_2/\sum_{i=1}^{7}\lambda_i)F_2+(\lambda_3/\sum_{i=1}^{7}\lambda_i)F_3$$

III. RESULTS

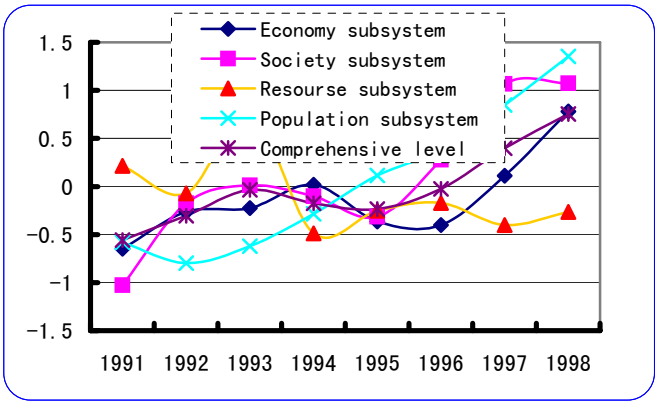
A. Comprehensive appraisal value of every subsystem

Using relevant materials of Honghu city from 1991 to 1998, according to the step of PCA method, we carry on the calculation of the comprehensive appraisal value to every subsystem, results are arranged in Tab 1. And then draw the developing state picture of every subsystem during this period according to Tab 1 (seeing Fig. 2).

Tab.1 Comprehensive Appraisal Value of Sustainable Development of Every Subsystem

Year	Economy Subsystem	Society Subsystem	Resource Environment Subsystem	Population Subsystem	Comprehensive Level
1991	-0.6468	-1.0281	0.2140	-0.5809	−0. 5577
1992	-0.2639	-0.1733	-0.0700	-0.7974	−0. 3031
1993	-0.2248	0.0115	0.7679	-0.6210	−0. 0355
1994	0.0189	-0.1031	-0.4891	-0.2837	−0. 1756
1995	-0.3661	-0.3132	-0.2530	0.1164	−0. 2362
1996	-0.4022	0.2791	-0.1719	0.3821	−0. 0252
1997	0.1107	1.0671	-0.4021	0.8461	0. 3982
1998	0.7802	1.0735	-0.2643	1.3531	0. 7533

Fig.2 the Sustainable Developing State of Honghu City



B. Appraise the comprehensive level of sustainable development of Honghu city

In order to know the system wholly, it is necessary to appraise the comprehensive level of sustainable

development of Honghu city. Each subsystem has different weight among the whole system. So we adopt expert judge law to confirm the weight of every subsystem. Through consulting four experts who have relatively further study to the state of development of Honghu, we draw the relative weight of every subsystem, arrange in Tab 2.

Tab.2 Weigh Value of Every Subsystem

	E1	E2	E3	E4	Average
Economy	0.35	0.33	0.32	0.36	0.34
Society	0.30	0.24	0.25	0.26	0.2625
Resource environment	0.15	0.21	0.23	0.23	0.205
Population	0.20	0.22	0.2	0.15	0.1925

According to the weight value, we carry on adding to every subsystem value, and get the comprehensive development level value of Honghu, in the Tab1, too. In order to contrast conveniently, also draw the developing state picture in Fig2.

C. Analyzing the appraisal results

According to above calculation procedures we obtain the comprehensive appraisal value of the system. This value can reflect development state of the system. Greater number value reflects more rational state of development. From the appraisal result, we can know the whole system is in course of circuitously developing ahead.

Development state of population subsystem is better, from 1991 to 1998. The birthrate and natural growth rate both present the downward trend. But while keeping good development state we should still pay attention to controlling the population size, improving the people quality. Because the size of population of this city is relatively high, and teacher's number presents the downward trend.

Economy subsystem is rising circuitously. Combining statistical data of Honghu city, we find many factors such as GDP, output value of the secondary industry, the tertiary industry of this city, etc. all showing a tendency to rise steadily. Developing state of the output value of primary industry and tax rate of the fund are identical with system developing state. Primary industry is dominant before 1994 in this city. Its proportion was lighter and lighter after 1994. This proves that primary industry has not got steady development in this city. And attention to agriculture is not enough. In addition, the utilization ratio of the fund is not high. The input-output ratio is difficult to get the effective assurance, which proved the city has not formed a kind of really high-efficient industrial structure yet.

The developing state of the society subsystem and economic subsystem are identical better, keep rising circuitously. This just proves the society development is closely linked with economy.

The state of the resource environment subsystem fluctuated before 1994, but obviously better than after 1994. After 1994, the secondary industry began to develop rapidly. The destruction of the environment follows too, which reflects fragility of the system deeply. While pursuing economy and social development we must pay attention to the protection of the environment and sustainable utilization of resources.

From the comprehensive results, we can know the whole system has a tendency of circuitous development ahead. The whole development state is identical better with society and economy subsystem. This approve the development of the whole system is mainly depending on the development of economic and social subsystem in this system. The impact of resource environment subsystem is not big, but the long-term influence is far-reaching. That is a main reason that resource and environment does not arouse people enough attention at present.

Ⅳ. CONCLUSIONS

With The Principal Component Analysis (PCA) method, using such existing quantity data as the yearbook and other regional statistical data, etc. we can conveniently carry on quantitative analysis and appraisal to the comprehensive situation of regional sustainable development.

This method synthesizes many linked analyzing factors to a few main factors by lowing dimension, turns analysis index into the comprehensible index which can describes the current situation of sustainable development, and concisely reveals the leading factor and space differentiation law of regional sustainable development.

The analyzed instance indicates: the analysis result has reflected the current situation of the development of the area objectively, and can offer the theoretical foundation for the administrative departments that make the development scheme and policy.

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